Electric and magnetic QT iso-integral maps in patients with and without coronary artery disease under pharmacologically induced stress

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1 Introduction

In patients with suspected coronary artery disease (CAD), stress testing is a standard clinical diagnostic procedure. For instance, changes in the electrocardiogram (ECG) are used as a marker for myocardial ischemia. The use of body surface potential mapping (BSPM) has also been investigated in CAD both at rest and under conditions of dynamic stress [1,2]. The latter have demonstrated that patients with single and multiple vessels disease show changes in particular during repolarization [3].

BSPM has also been performed in conjunction with magnetic field mapping (MFM) in healthy subjects at rest [4] and under stress [5,6]. These studies showed a large degree of correspondence between the electric and magnetic fields whereby differences during ST and T wave intervals have been noted. Some work has been done on MFM in patients with CAD without myocardial infarction (MI) at rest and stress demonstrating differences between spatial as well as temporal aspects of the magnetic maps of patients with and without significant stenosis of one or more coronary artery [7,8,9]. The aim of this study was to examine stress induced changes in both electric and magnetic iso-integral maps during the QT interval in subjects with and without CAD.

2 Methods

We investigated 5 patients who were admitted to hospital with suspected CAD and who underwent rest and stress 12 lead ECG and echocardiography. Prerequisite for admission to the study was a normal rest ECG. Wall motion disturbances were detected in subject 5 under stress, and ST depression were found in subject 4 under stress. Patient characteristics are summarized in Table 1.

Prior to left heart catheterization, simultaneous 32 lead ECG (Biosemi, Amsterdam) and 61 channel magnetocardiograms (MCG) (BTi, San Diego) were registered for 100 s with a bandpass of 0.1-200 Hz and a sampling rate of 1 kHz in a shielded environment. Data were recorded for 100 s both at rest and under dobutamine induced stress (target heart rate: 120 bpm). Both the rest and stress raw data were processed as follows: 1) beats were identified and selectively averaged, 2) the 32 ECG leads were transformed into a 192 lead grid (according to [10], see Fig. 1) and 3) iso-integral maps were reconstructed for QRS, ST and T wave intervals for both the ECG and the MCG data. ST and T wave were defined as 3/8 and 5/8 of the ST-T interval, respectively. For both the BSPM and MFM, the location and value of the positive and negative field extrema were determined and the correlation between the respective rest and stress maps were calculated.

Table 1: *Patient characteristics (EF: ejection fraction, HR_r HR_s: heart rate at rest and under stress, LAD: left anterior descending artery, CX: circumflex, RCA: right coronary artery).*

Pat.	sex	age yrs	affected vessels	EF %	HR_r bpm	HR_s bpm
1	f	65			63	158
2	m	64			70	133
3	m	47	LAD	70	71	124
4	m	41	LAD CX	63	49	122
5	m	73	LAD CX RCA	74	58	133

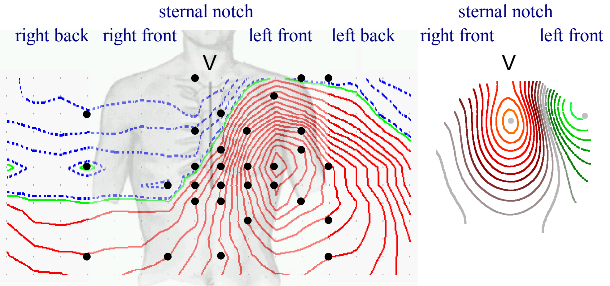

Figure 1: *left: BSPM QRS integral maps showing its position relative to the frontal thorax and the location of the 32 ECG leads; right: corresponding MFM over the frontal thorax.*

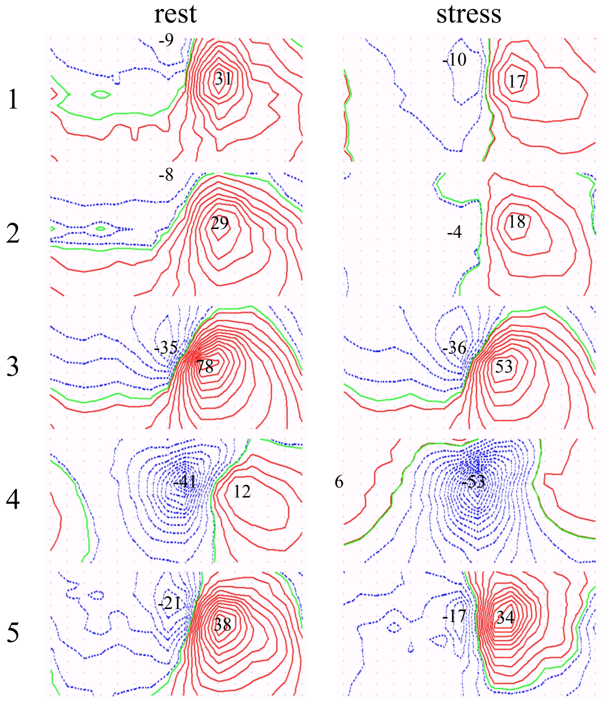

Figure 2**:** *BSPM QRS integral maps of subjects 1-5 at rest and under stress. Extrema are given in µV*s, isocontour line steps = 3µV*s (subj. 3: 6µV*s).*

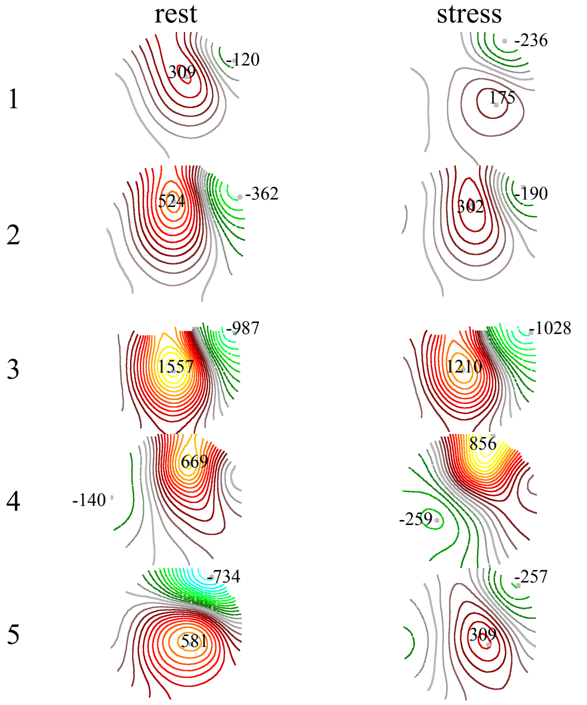

Figure 3**:** *MFM QRS integral maps of subjects 1-5 at rest and under stress. Extrema are given in fT*s, isocontour line steps = 50 fT *s (subj. 3: 100 fT *s).*

3 Results

Heart rate values at rest and under pharmacologically induced stress are given in Table 1. At rest the electric QRS integral maps of subjects 1, 2, 3 and 5 displayed positive values over the mid left, negative values over the upper right anterior thorax (Fig. 2). The negative values of subjects with affected coronary arteries (3, 4, 5) tended to cover more of the right anterior thorax, in subject 4, the whole anterior thorax. Under stress, the negative values in subjects 1, 2, 3 and 5 extended further caudally and to the left whereby the intra-individual correlation between the rest and stress maps remained high (Table 2).

Magnetic QRS integral maps at rest showed predominantly positive values over the frontal thorax with negative values at the upper left, subject 4 again being the exception (Fig. 3). Subject 2-5 showed minimal change under stress as evidenced by high r values (Table 2). The greater dissimilarity between the rest and stress maps of subject 1 may be due to her relatively high heart rate under stress.

The absolute integral values in both BSPM and MFM were higher for the subjects with CAD under both conditions, and they decreased in subjects 1-3 and 5 under stress.

The electric ST integral maps were largely positive, centered over the anterior thorax, subject 5 being the exception (Fig. 4). Under stress all subjects demonstrated an increase in negative values caudally and on the left anterior and posterior thorax. Accordingly, the r values were low (Table 2), indicating dissimilarity between rest and stress maps.

The magnetic ST integral maps displayed predominantly positive values on the frontal thorax with negative values visible on the upper or mid-left (Fig. 5). In subjects 1-3 and 5, there was an overall inversion of the values under stress, as reflected in the negative r values (Table 2).

Table 2: *Comparisons between rest and stress QRS, ST and T wave integral maps: correlation coefficients r for BSPM and MFM.*

Pat.	QRS		ST		T wave	
	BSPM	MFM	BSPM	MFM	BSPM	MFM
1	.83	.62	.24	-.76	.96	.65
2	.86	.94	.26	-.57	.89	.92
3	.99	.97	.57	-.67	.99	.93
4	.79	.87	.62	.74	.97	.95
5	.71	.81	-.09	-.76	.29	.78

The absolute integral values in both BSPM and MFM tended to be higher for the subjects with CAD under the two conditions, and they decreased in subjects 1, 3 and 4 under stress.

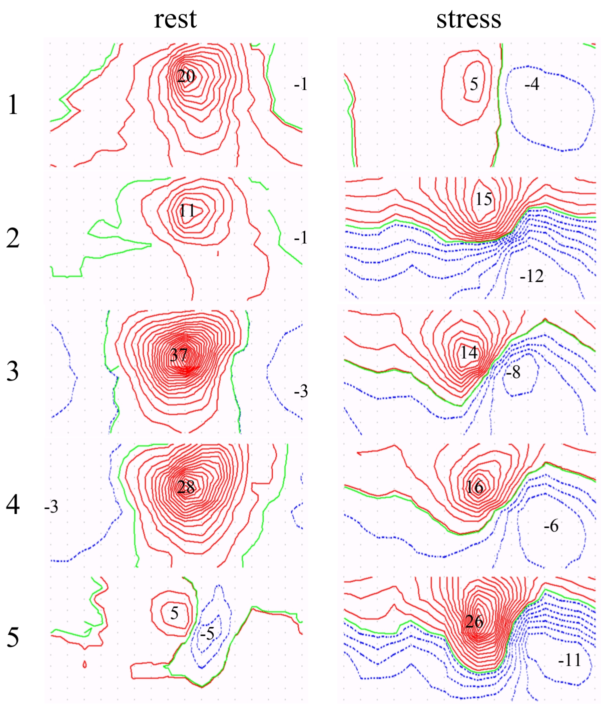

Figure 4: *BSPM ST integral maps of subjects 1-5 at rest and under stress. Extrema are given in µV*s, isocontour line steps = 1.5µV*s.*

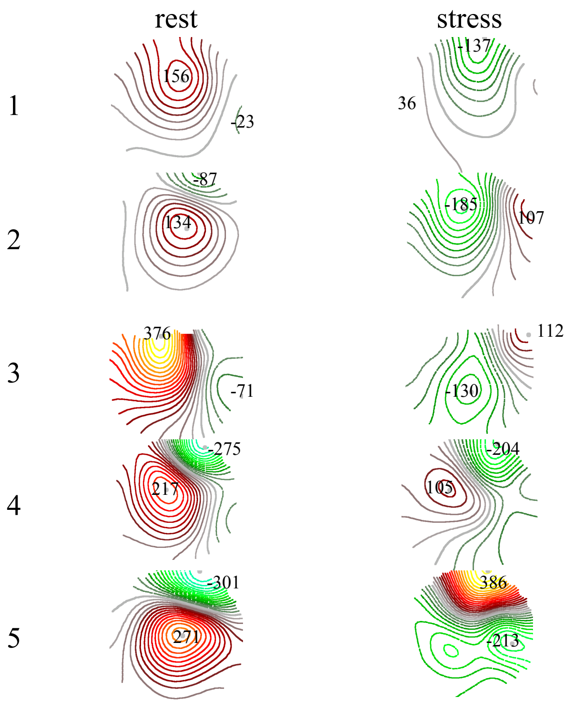

Figure 5: *MFM ST integral maps of subjects 1-5 at rest and under stress. Extrema are given in fT*s, isocontour line steps = 20 fT *s.*

The electric T wave integral maps at rest (Fig. 6) displayed distributions similar to the rest QRS integral maps (Fig. 2) and, except in subject 5, changed very little under stress. In four subjects (2-5) the field minimum shifted to the left posterior.

The magnetic T wave integral maps at rest (Fig. 7) were also similar to the corresponding QRS integral maps (Fig. 3). The stress map of subject 1 again showed the greatest dissimilarity whereas the stress map of subject 5 displayed more similarity to his rest map than the corresponding electric maps. Also there was a small but consistent shift to the right in the MFM under stress: the minimum and the maximum values were displaced by approximately 2 cm in four of the five subjects.

The absolute integral values in both BSPM and MFM again tended to be higher for the subjects with CAD under both conditions, and they decreased clearly in all subjects under stress.

4 Discussion

Although the number of subjects investigated was small, a few tendencies can be noted in the results. During stress, there was an overall trend to lower integral values in the QRS and T wave integrals. In the ST integral the changes were ambiguous. Concurrently, for the QRS and T wave integrals, the distribution of the positive and negative values tended to be the same in rest and stress as reflected in the high intra-individual correlation coefficients. For the ST integrals under stress, the distribution changed considerably for BSPM and inverted for MFM. This indicates a higher sensitivity of the ST segment to the stress challenge which has also been previously noted [1]. Furthermore the inversion of the ST integral MFM is in agreement with findings of Brockmeier et al [5] who described similar MFM inversion during ST-T in healthy subjects under stress which were not evident in BSPM. Also of interest is the small but consistent shift in the T wave integral MFM under stress. Takala et al. [4] reported a similar spatial shift at T maximum in healthy subjects in MFM recorded immediately after bicycle exercise for which they found corresponding change in the simultaneously registered BSPM. The reason for these discrepencies between MFM and BSPM are still subject of discussion.

With respect to the presence of stenosis of one or more coronary artery, we found that, compared to the patterns of the maps of patients without CAD, maps in multiple vessel disease deviated more than those in single vessel disease. In other words, the degree of deviation from the results of the normal subjects tended to be dependent on the severity of CAD. However, due to the small number of subjects and the variety of vessels affected, general conclusions cannot be drawn.

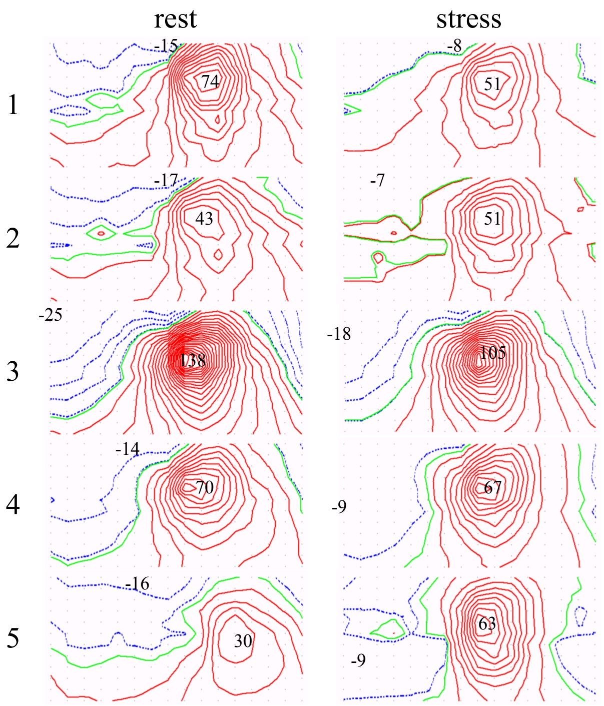

Figure 6**:** *BSPM T wave integral maps of subjects 1-5 at rest and under stress. Extrema are given in µV*s, isocontour line steps = 6µV*s.*

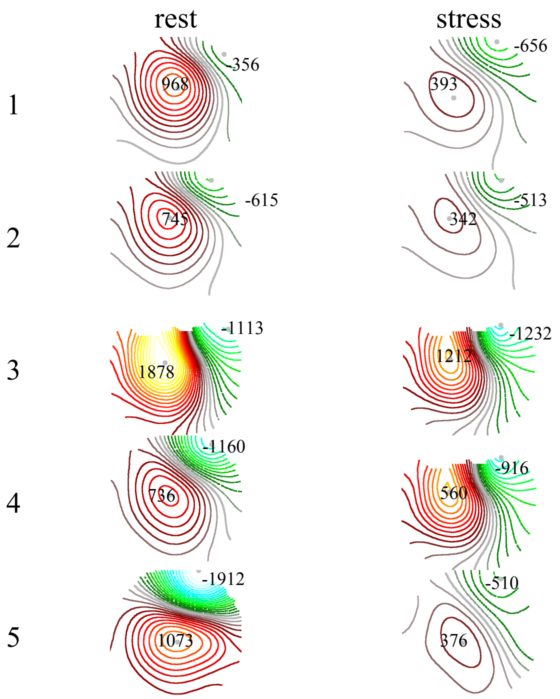

Figure 7**:** *MFM T integral maps of subjects 1-5 at rest and under stress. Extrema are given in fT*s, isocontour line steps = 100 fT *s.*

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